Extension of Operation Range of Semiconductor Optical Add and Drop Multiplexer

M. Horita, T. Yazaki, S. Tanaka and Y. Matsushima
KDD R&D Labs. Inc., Kamifukuoka-shi, Saitama, Japan, E-mail: horita@kddlabs.co.jp

An optical add and drop multiplexer (OADM) plays an important role in optical networks based on WDM transmission systems. We have proposed, and experimentally and theoretically studied a vertically and contra-directionally coupled semiconductor waveguide type OADM (VECCS-OADM) from the viewpoints of narrow-band wavelength selectivity, tunability and compactness [1-4]. A schematic view of the tunable VECCS-OADM with a striped thin-film heater in an InGaAsP/InP material system is depicted in Fig. 1. Contra-directional coupling between two dissimilar waveguides was utilized as the operation mechanism in the device. Two other peaks, which are due to in-waveguide coupling in two respective waveguides, appear in transmission spectra near the Bragg wavelength of the contra-directional coupling between two waveguides. This is an inherent limiting factor for the operating range of the VECCS-OADM, and the operating range was typically 10 nm in conventional devices with the same waveguide materials. The peaks due to in-waveguide coupling can be moved away from the main Bragg wavelength by increasing the difference of effective refractive index Δn_{eff} between two waveguides. The VECCS-structure is advantageous in the flexibility of waveguide design because the refractive index of two waveguides can be controlled independently over a relatively large range. In this paper, we investigate the contra-directional coupling between waveguides with a large Δn_{eff} theoretically and experimentally.

Numerical calculations were carried out, based on the finite element method and coupled mode theory. The waveguide model used here is depicted in Fig. 2. Two vertically stacked InGaAsP rib waveguides in InP cladding are considered. A uniform grating is located in the middle of the waveguides. Fig. 3 shows calculated spectra of a device with n_l=3.36 and n_u=3.44, these values corresponding to a λg of 1.24 μm and 1.40 μm, respectively, and Δn_{eff} is 3 %. The peak and dip at 1560 nm are due to the contra-directional coupling between the lower and upper waveguides. The peaks at 1538 nm and at 1582 nm are due to the in-waveguide contra-directional coupling in the lower and upper waveguides, respectively. The distance between each peak was 22 nm. We found that an operating range of more than 40 nm could be expected by using the dissimilar waveguides with a Δn_{eff} of 3 %.

Devices with ridge and rib waveguides were fabricated by three-step metal organic vapor phase epitaxy. The thicknesses of the lower and upper waveguides and the separation layer were 0.6 μm, 0.6 μm and 0.5 μm, respectively. The λg of the lower and upper waveguides was 1.2 μm and 1.4 μm, respectively. The grating was not apodized, and the period, depth and coupling length of the grating were 240 nm, 100 nm and 3 mm, respectively. Both facets were AR-coated. Fig. 4 shows the transmission spectra for TM modes. The main peak at 1560 nm is considered to be due to the contra-directional coupling between two waveguides. The 3 dB bandwidth was 0.2 nm. A dip at 1540 nm is attributed to the in-waveguide coupling in the lower waveguide, and it was separated by 20 nm from the main peak. Neither peaks nor dips were observed in the range from 1540 nm to 1600 nm except for the Bragg coupling, and wide operating range of more than 40 nm was confirmed experimentally.

In conclusion, the contra-directional coupling between waveguides with a large Δn_{eff} was investigated in order to extend operating range of the VECCS-OADM. Numerical calculations and experiments were performed, and the operating range of the device was successfully extended to more than 40 nm by using the dissimilar waveguides with a Δn_{eff} of 3 %.

References [1] S. Tanaka, et al., IPRM'96, TuP-C23. [2] M. Horita, et al., Electron. Lett., **34**, 2340 (1998). [3] M. Horita, et al., Electron. Lett., **35**, 1733 (1999). [4] M. Horita, et al., IPRM'00, WA2.5.

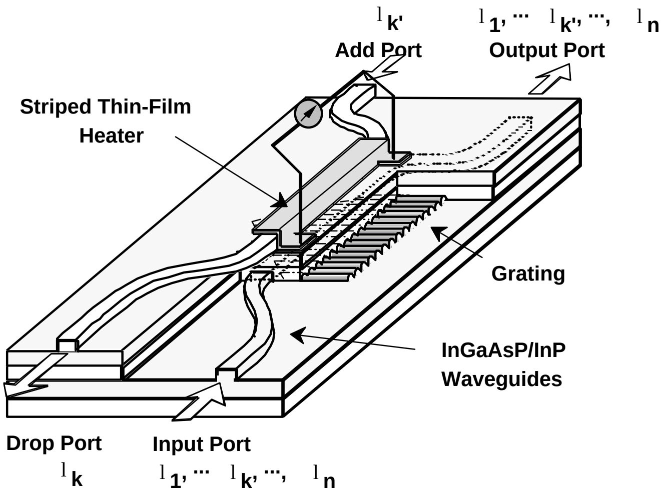

Fig. 1: Basic structure of the VECCS-OADM with a striped thin-film heater.

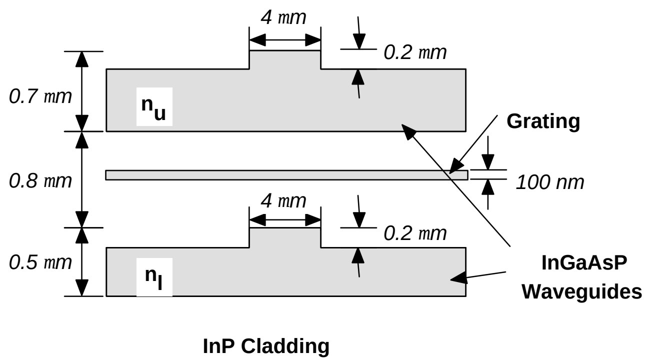

Fig. 2: A waveguide model for calculations.

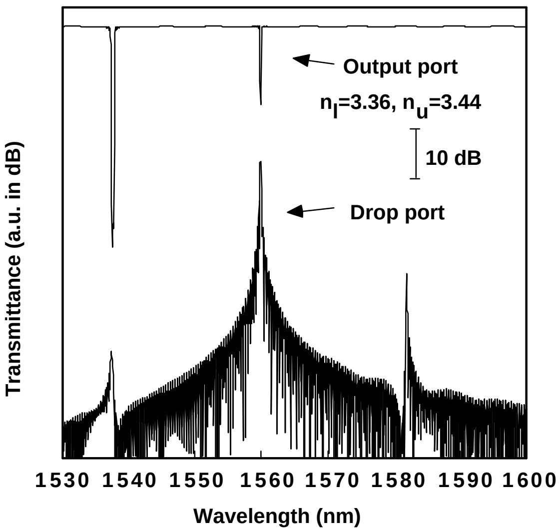

Fig. 3: Calculated spectra for TM-mode of the output light of a device with n_l= 3.36 and n_u=3.44.

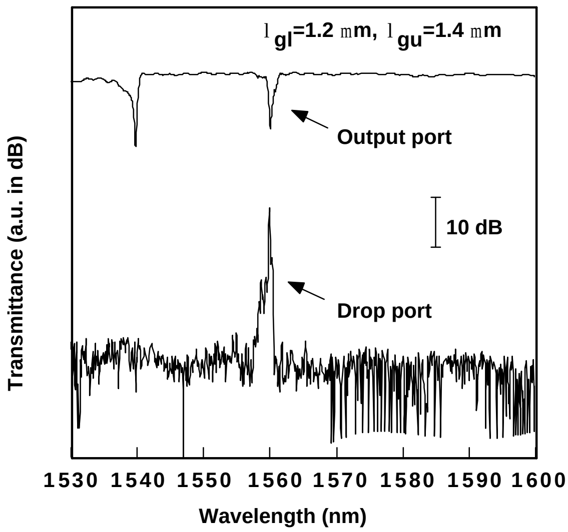

Fig. 4: Output spectra for TM-mode of a fabricated device with l $_{gl}$= 1.2 mm and l $_{gu}$= 1.4 mm.